SEMICONDUCTOR STRUCTURE AND PROCESS FOR FORMING OHMIC CONNECTIONS TO A SEMICONDUCTOR STRUCTURE

BACKGROUND OF THE INVENTION

[0001] 1. Field of Invention

[0002] The present invention generally relates to semiconductor devices and more particularly to forming ohmic connections between external conductors and semiconductor devices.

[0003] 2. Description of Related Art

[0004] Making ohmic contact to a semiconductor device typically involves deposition of a contact metal by screen printing, sputtering, evaporation, or chemical vapor deposition. The device is then generally annealed to cause the metal to at least partly diffuse into the semiconductor material to create an internal ohmic contact. Generally the process is time and energy consuming, complicated, and may be expensive to implement, particularly for large area semiconductor devices such as photovoltaic cells.

[0005] Crystalline silicon photovoltaic (PV) cells are generally produced from a wafer having a p/n junction. The p/n junction may be produced by diffusion of either phosphorus or boron into a front side of a p-type or n-type semiconductor substrate. A portion of the PV cell, between its front side and the p/n junction creates what is known as an emitter. Under illumination by light the PV cell generates electric current as a result of charge separation within the p/n junction area. This electric current is collected from the PV cell by front and back side metal contacts.

[0006] The metal contacts are typically provided through the use of screen printing technology, involving a partially electrically conductive paste, which typically contains silver and/or aluminum, which is screen printed onto front and back surfaces of the cell through a mask.

[0007] For the front side of the PV cell, the mask typically has openings through which the conductive paste contacts the semiconductor substrate surface. The front side mask is typically configured to produce a plurality of thin parallel line contacts and two or more thicker lines that are connected to, and extend generally perpendicular to the parallel line contacts. After spreading paste on the mask, the mask is removed and the wafer bearing the partially conductive paste is heated to dry the paste. The wafer is then "fired" in an oven and the paste enters a metallic phase, where at least part of it diffuses through the front surface of the solar cell and into the cell structure while a portion is left solidified on the front surface. The multiple thin parallel lines thus form thin parallel linear current collecting areas referred to as "fingers", intersected by thicker perpendicular lines referred to as "bus bars". The fingers collect the electrical current from the front side of the PV cell and transfer the current to the bus-bars.

[0008] Typically, the width and the height of each finger is approximately 120 microns and 10 microns respectively. While the fingers are sufficient to collect small electric currents from the PV cell, the bus-bars are required to collect a much greater current from the plurality of fingers and therefore have correspondingly larger cross section and width.

[0009] For the back surface of the PV cell a partially conductive paste containing aluminum is spread over the entire back surface of the cell except for a few small areas. The past is dried by heating (generally simultaneous with the heating of the front side paste). Then silver/aluminum paste is screen printed in certain areas that have not been printed with aluminum paste and the paste is dried by a further heating step. When the wafer is subjected to "firing" in the oven, part of the aluminum diffuses into the back surface of the PV cell which produces a highly doped p+ layer, or back surface field (BSF). The aluminum also alloys with the silver/aluminum paste and forms silver/aluminum pads. The back surface field collects electrical current from rear side of PV cell and conducts it to the silver/aluminum pads, which act as terminals from the PV cell.

[0010] The area that is occupied by the fingers and bus bars on the front side of the solar cell is known as the shading area because solar radiation is prevented from reaching the solar cell surface in this area. This shading area decreases solar cell conversion efficiency. Modern solar cell shading occupies 6-10% of the available solar cell surface area. The presence of metal contacts on the front side and the silver/aluminum pads on the back side results in a decrease of voltage generated by the PV cell in proportion to the metalized area. Furthermore, diffusion of the contact metal into the front surface of the PV cell has a detrimental effect on charge recombination.

[0011] Conventional metallization techniques may also introduce bowing of the solar cell due to the difference in thermal expansion coefficients between silicon material and silver/aluminum pastes. Bowing may be very pronounced on thin solar cells, which may be less than 180 micron thick, making such cells fragile thus reducing production yield.

[0012] U.S. Pat. No. 6,982,218 entitled Method of Producing a Semiconductor-Metal Contact through a Dielectric Layer to Preu et al., describes a method of electrically contacting a semiconductor layer coated with at least one dielectric layer. The metal layer is applied over the dielectric layer and is temporarily locally heated in linear or dotted patterns by means of a controlled source of radiation. The heating causes a localized molten mixture of the metal layer, the dielectric layer, and the semiconductor layer. The dielectric layer and semiconductor layer are located directly underneath the metal layer and upon solidification, provide an electric contact between the semiconductor layer and the metal layer. The Dielectric layer is very thin (less than 1 micron and preferably in the range from 10 nanometers to 500 nanometers) and metal layer is preferably aluminum of approximately 2 micron thickness. The thin metal layer generally does not produce the bowing effect, even when used with very thin silicon wafers. This method may be attractive for mass production of efficient PV cells due to the efficient passivation of their back side after the dielectric layer is applied according to the proposed method. At the same time the need to use an additional coating of aluminum with an intermediate metallic layer in order to arrange reliable electrical contacting with electrical leads still appears to be a problem.

[0013] International Application WO 2004/021455 entitled "Electrode for Photovoltaic Cells, Photovoltaic Cell and Photovoltaic Module", to Rubin et al. describes a current collecting electrode employing a low melting point alloy that is able to establish low resistive contact with a conductive antireflection coating that is applied on the front side of a PV cell and with back side screen printed aluminum metallization. This technology eliminates the need for conventional screen printing metallization on the front side of